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Journal
Global spine journal, 7(7)

ISSN
2192-5682

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Publication Date
2017-10-01

DOI
10.1177/2192568217716151

Peer reviewed

Global Spine Journal
2017, Vol. 7(7) 703-708

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DOI: 10.1177/2192568217716151
journals.sagepub.com/home/gsj

Is There a Patient Profile That Characterizes a Patient With Adult Spinal Deformity as a Candidate for Minimally Invasive Surgery?

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Abstract

Study Design: Retrospective review.

Objectives: The goal of this study was to evaluate the baseline characteristics of patients chosen to undergo traditional open versus minimally invasive surgery (MIS) for adult spinal deformity (ASD).

Methods: A multicenter review of 2 databases including ASD patients treated with surgery. Inclusion criteria were age >45 years, Cobb angle minimum of 20°, and minimum 2-year follow-up. Preoperative radiographic parameters and disability outcome measures were reviewed.

Results: A total of 350 patients were identified: 173 OPEN patients and 177 MIS. OPEN patients were significantly younger than MIS patients (61.5 years vs 63.74 years, $P = .013$). The OPEN group had significantly more females (87% vs 76%, $P = .006$), but both groups had similar body mass index. Preoperative lumbar Cobb was significantly higher for the OPEN group (34.2°) than for the MIS group (26.0°, $P < .001$). The mean preoperative Oswestry Disability Index was significantly higher in the MIS group (44.8 in OPEN patients and 49.8 in MIS patients, $P < .011$). The preoperative Numerical Rating Scale value for back pain was 7.2 in the OPEN group and 6.8 in the MIS group preoperatively, $P = .100$.

Conclusions: Patients chosen for MIS for ASD are slightly older and have smaller coronal deformities than those chosen for open techniques, but they did not have a substantially lesser degree of sagittal malalignment. MIS surgery was most frequently utilized for patients with an sagittal vertical axis under 6 cm and a baseline pelvic incidence and lumbar lordosis mismatch under 30°.

Keywords

minimally invasive, adult deformity, adult scoliosis

Introduction

Adult spinal deformity (ASD) can have a profoundly negative impact on an individual's well-being, as has been confirmed utilizing health-related quality-of-life (HRQOL) measures.[1] Surgery to correct such ASD has been shown to result in significant improvement in these HRQOL measures.[2-7] Traditional open techniques for correction of these deformities carry substantial risks of morbidity, and typically result in prolonged hospitalizations and slow recovery.[8,9] Complication rates have been found to range up to 53% in a recent systematic review[10] of traditional open adult deformity surgery, while Street et al found at least one complication occurred in 87%

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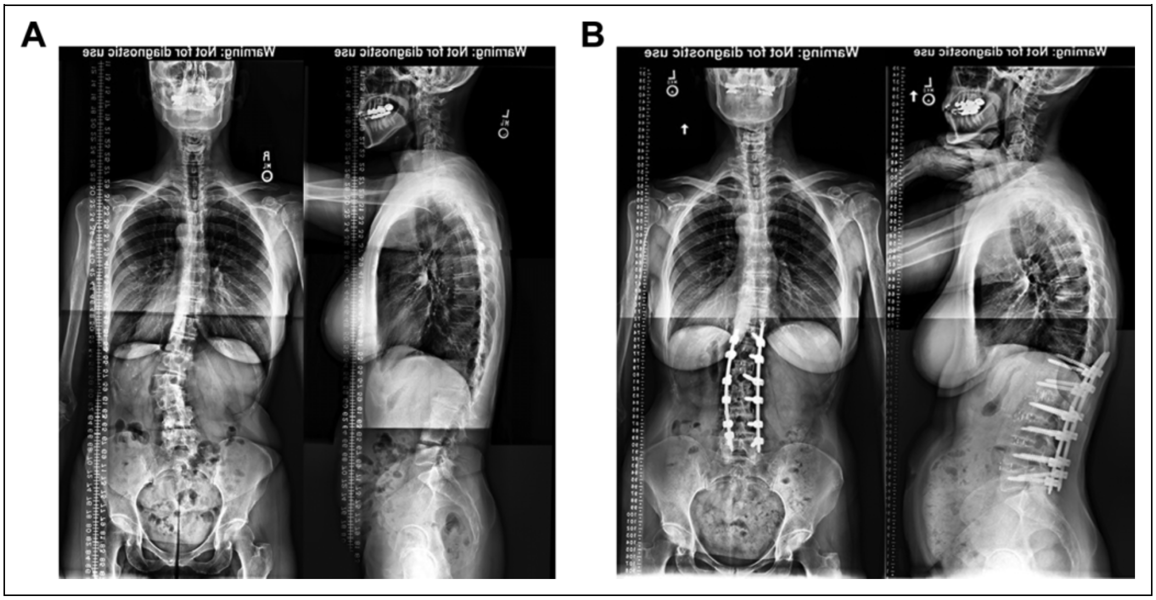

Figure 1. Anteroposterior and lateral long-alignment films of a patient in the cMIS subgroup preoperatively (A) and postoperatively (B). Reprinted with permission from Behrooz A. Akbarnia, MD, San Diego Center for Spinal Disorders.

of the 942 patients they studied prospectively.[11] Given the considerable morbidity associated with performing traditional open ASD correction, there has been an interest in utilizing minimally invasive techniques in an effort to diminish these shortcomings. Consequently, minimally invasive techniques have recently been devised and employed to perform corrective surgery for ASD.[12-19] While some authors have shown a considerable average deformity correction, others have represented series of patients that suffered from milder degrees of preoperative deformity. For instance, Anand et al reported on 50 patients with preoperative coronal deformities that ranged from 30° to 75°.[20] On the other hand, Dakwar et al reviewed 25 patients treated with minimally invasive surgery (MIS) techniques, and the preoperative Cobb angles were relatively milder, ranging from 10° to 49°.[15] This variance in the degree of deformities represented in the early literature published on minimally invasive adult deformity correction leads to some uncertainty as to which patients can or should be chosen for these techniques. Work by Mummaneni and others recently led to the creation of an algorithm for use when considering minimally invasive techniques in ASD surgery, which was based on early experience with these methods of treatment.[13] However, it is unclear whether these newer MIS techniques are interchangeable with traditional open deformity correction techniques with respect to the degree or type of preoperative deformity.

Methods

A retrospective review was performed involving 2 ASD databases—one prospective multicenter and one retrospective multicenter (minimally invasive). The patients were captured consecutively on a multicenter basis, and following institutional review board approval of the protocol at each site. Patients in the prospective database who had undergone any MIS techniques for correction were excluded from use in the comparison, such that only patients undergoing traditional open (OPEN group) deformity correction without 3-column osteotomies were utilized. All patients who had minimally invasive techniques employed as a portion of the surgical correction/technique (MIS group) were derived from the retrospective multicenter database (see Figures 1 and 2 for examples of each procedure). Inclusion criteria were age $\geq$45 years, lumbar major Cobb angle >20°, and minimum 2-year follow-up. Demographic information, including age and gender, was identified at baseline preoperatively for all patients. Minimally invasive surgical techniques included nontraditional anterior or posterior approaches to perform surgical correction of the ASD. These techniques included lateral lumbar interbody fusion (LLIF), MIS transforaminal lumbar interbody fusion (TLIF), and transsacral lumbar interbody fusion (AxiaLIF). A separate subgroup analysis of the MIS group included those who underwent circumferential MIS (cMIS) techniques for deformity correction and those who underwent partial MIS and partial open technique (HYBRID) for correction, such as LLIF combined with an open posterior approach.

Full-length anteroposterior and lateral spine radiographs (36-inch-long cassette X-rays) were obtained for baseline analysis, and they were analyzed using validated software (Spineview, ENSAM, Laboratory of Biomechanics, Paris, France). All radiographic measures were performed at a central location (NYU) based on standard techniques and included the following: lumbar lordosis (LL; the sagittal Cobb angle between superior endplate of L1 and superior endplate of S1), sagittal vertical axis (SVA; the sagittal C7 plumbline relative to the posterior, superior aspect of the S1 endplate), pelvic tilt (PT), pelvic incidence (PI), the mismatch between pelvic incidence and lumbar lordosis (PI-LL), and lumbar major coronal Cobb angle (Cobb-lumbar). Baseline HRQOL and preoperative

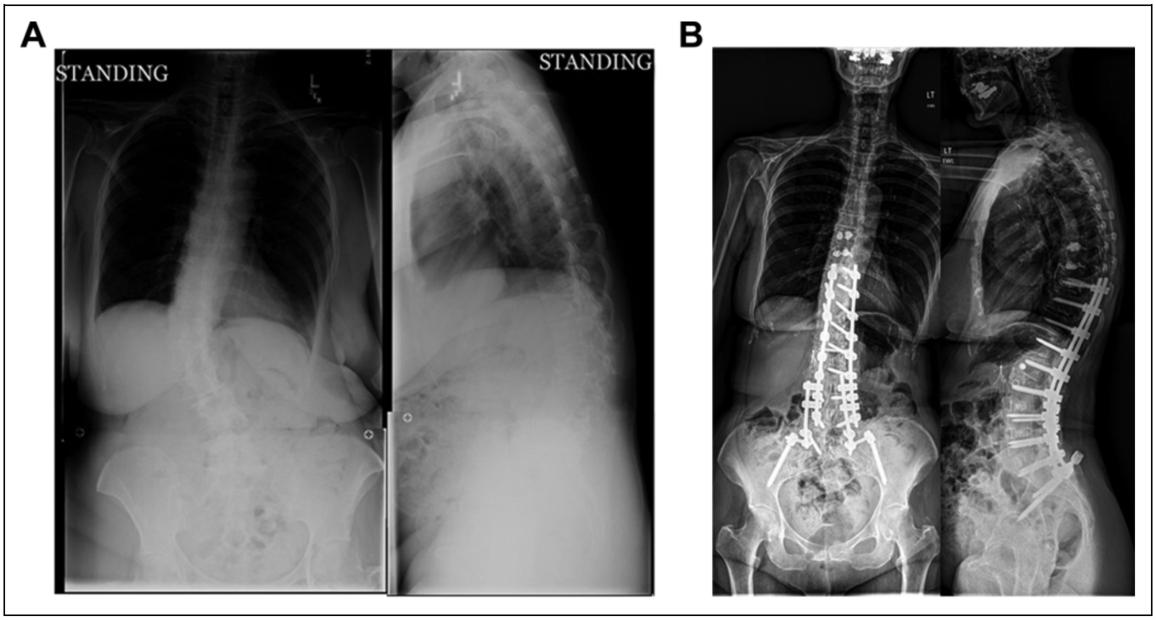

Figure 2. Anteroposterior and lateral long-alignment films of a patient in the OPEN subgroup preoperatively (A) and postoperatively (B). Reprinted with permission from Behrooz A. Akbarnia, MD, San Diego Center for Spinal Disorders.

Table 1. Comparison of Baseline Demographic and Outcome Characteristics Between Open and MIS Groups and Between Open and CMIS and Hybrid Subgroups.

	OPEN	MIS	*P*	cMIS	*P*	HYBRID	*P*
N	173	177		98		79	
Age (years)	61.5	63.7	.013*	64.2	.009*	63.0	.172
Females	149 (87.1%)	135 (76.3%)	.009	75 (76.5%)	.025	60 (75.9%)	.026
BMI	27.6	27.3	.723	27.5	.926	27.1	.602
Preoperative NSR Back	7.2	6.8	.100	6.7	.033*	7.1	.591
Preoperative NSR Leg	5.0	5.9	.009*	5.9	.014*	5.8	.078
Preoperative ODI	44.8	49.8	.011*	47.9	.172	52.2	.004*

Abbreviations: MIS, minimally invasive surgery; BMI, body mass index; NSR, numeric rating scale; ODI, Oswestry Disability Index.
*Significantly different from OPEN at $P < .05$

disability were measured with Oswestry Disability Index (ODI) and numerical rating scale (NRS) values.

Statistical analysis was performed utilizing an independent t test, and χ^2 analysis was used to compare groups. The statistical analyses were conducted using commercially available software (IBM Statistical Package for the Social Sciences [SPSS] v.20.0; Armonk, NY), and the level of significance was established at $P < .05$.

Results

A total of 350 patients met inclusion criteria. There were 173 patients in the OPEN group and 177 patients in the MIS group. Within the MIS group, 98 patients satisfied criteria for cMIS designation, while 79 fell into the HYBRID subcategory. Of the 98 patients in the MIS group, 11 underwent transsacral fixation technique for lumbosacral interbody arthrodesis. Patients in the OPEN group had an average age of 61.5 years, while those in the MIS group had an average age of 63.7 years of age ($P = .013$; see Table 1). cMIS patients were slightly older with an average age of 64.2 ($P = .009$) when compared with the OPEN group. Both groups were predominantly female, but there was significantly more female predominance within the OPEN group when compared to the MIS group (87% vs 76%, $P = .006$). There were similar baseline body mass indices (BMI) between OPEN and MIS groups.

The preoperative lumbar Cobb angular deformity was significantly higher for those patients undergoing open surgery (34.2°), when compared with those patients who were treated with a minimally invasive approach (26.0°, $P < .001$; see Table 2). Notably, when comparing the cMIS and HYBRID subgroups separately with OPEN patients, these differences were maintained (25.6° for cMIS and 26.4° for HYBRID, both $P < .001$), and there was no significant difference between cMIS and HYBRID patient groups.

The preoperative SVA averaged 5.7 cm for patients in the OPEN group, which was not significantly different from the 4.8 cm found in the MIS group ($P = .183$). Notably, when

Table 2. Comparison of Baseline Radiographic Characteristics Between Open and MIS Groups and Between Open and CMIS and Hybrid Subgroups.

	OPEN	MIS	*P*	cMIS	*P*	HYBRID	*P*
N	173	177		98		79	
Thoracic kyphosis	30.8	30.9	.967	32.8	.336	28.6	.319
Cobb-lumbar (°)	34.2	26.0	<.001*	25.6	<.001*	26.4	.001*
SVA (cm)	5.7	4.8	.183	4.2	.056	5.6	.889
LL (°)	39.9	38.2	.410	38.8	.623	37.6	.388
PI-LL mismatch (°)	14.2	17.2	.116	15.3	.616	19.3	.400
PT (°)	23.3	24.9	.151	25.0	.190	24.7	.284

Abbreviations: MIS, minimally invasive surgery; cMIS, circumferential MIS; SVA, sagittal vertical axis; LL, lumbar lordosis; PI, pelvic incidence; PT, pelvic tilt.
*Significantly different from OPEN at $P < .05$.

separating the MIS group into subgroups, comparison against the OPEN patients still did not reveal any significant differences in preoperative SVA for the cMIS patients (4.2 cm, $P = .056$) or the HYBRID patients (5.6 cm, $P = .889$), although there appears to be a potential trend toward a lower SVA with respect to the cMIS group.

Baseline preoperative lumbar lordosis was similar in patients undergoing open correction and patients in the minimally invasive correction group and subgroups (39.9° vs 38.2°, $P = .410$). Baseline PI-LL mismatch was also similar when comparing both primary groups (MIS = 17.2° vs OPEN = 14.2°, $P = .116$). However, the HYBRID subgroup demonstrated a significantly worse baseline PI-LL mismatch (19.3°, $P = .04$) compared with OPEN patients, while the cMIS patients did not (15.3°, $P = .616$). Preoperative pelvic tilt was also similar in both groups (OPEN = 23.3° vs MIS = 24.9°; $P = .151$), and this similarity was maintained through cMIS and HYBRID subgroup comparisons with OPEN.

With respect to baseline HRQOL measures, preoperative ODI was significantly worse in the MIS group (44.8 in OPEN and 49.8 in MIS; $P = .011$). This relationship was also true for both cMIS and HYBRID subgroups, when comparing them separately to the OPEN group. However, the preoperative NRS for back pain was similar in both groups (7.2 in the OPEN group and 6.8 in the MIS group, $P = .100$).

Discussion

Minimally invasive techniques are being more commonly employed for the operative management of ASD; however, it is unknown whether these techniques have been applied to patients with differential baseline demographic, radiographic, and HRQOL characteristics when compared with those patients undergoing traditional open techniques. In this study, we aimed to determine whether patients having surgical correction for ASD via minimally invasive methods were largely similar or considerably different with respect to baseline preoperative characteristics.

Based on our data, patients undergoing surgery for ASD through minimally invasive techniques are of similar gender and BMI, but they were slightly older than those having open surgery. This finding may represent a generally greater tolerance for deformity correction surgery in the older patient population, when utilizing less-invasive techniques. However, in this retrospective analysis there is no implication that younger patients preferentially underwent open procedures on the basis of what was performed. Rather, benefits of less invasive techniques might still be appreciated by this younger group. Reduced morbidity when performing spinal reconstruction in the elderly utilizing minimally invasive techniques in lieu of open techniques has been previously reported. Rodgers et al[21] and Rosen et al[22] found that octogenarians fared equally well to those in younger age groups with respect to complications and outcomes when minimally-invasive techniques were employed.

Preoperative HRQOL measures were similar regardless of the chosen surgical approach. This finding would suggest that the degree of preoperative disability or impairment in function does not play a significant role in selecting the type of technique to be employed when treating ASD.

With respect to radiographic parameters, our data shows that patients having traditional open techniques for ASD correction tend to have more severe coronal deformities in the lumbar spine. Interestingly, and somewhat unexpectedly, there was not a significant difference in preoperative sagittal profiles between patient groups.

Preoperative lumbar lordosis, pelvic incidence-lumbar lordosis mismatch, pelvic tilt, and SVA were each similar or insignificantly different when comparing open and MIS patient groups. However, there was a slight trend toward significant preoperative SVA differences when isolating cMIS patients from the HYBRID patients and comparing the cMIS subgroup against the OPEN group. The inability to detect statistical significance may have been the result of a reduction in the number of subjects for subgroup analysis. Notably, the average SVA for any of the groups was not markedly abnormal, and thus, the patients selected for the analysis through our inclusion criteria appear to have been predominantly affected by coronal deformity, rather than marked sagittal malalignment.

Limitations with our study include its retrospective nature at multiple sites and with a variety of surgeons, as well as its nonrandomized design. Consecutive recruitment of the patients in a prospective manner certainly reduces the potential for selection bias. However, retrospective studies by their nature introduce the potential for such bias in the data collection. In addition, ASD patients represent an extremely complex patient population, with considerable heterogeneity in factors not fully accounted for in this study, such as bone quality or the flexibility of the curves being treated. Ultimately, when incorporating new techniques, there is a potential selection bias on the basis of the surgeons being more apprehensive or limited in the application of novel techniques with more difficult cases initially. As experience with such techniques grows, along with technology advances, these biases in patient selection evolve commensurately. Additionally, despite analyzing for many baseline characteristics in these patient populations, it does not appear statistically appropriate in this particular study to utilize a multivariate analysis. In order to do so would require the application of logistic regression. The interpretation of the result of such a process would be lead to predicting the likelihood of using an MIS surgery with the covariates we are testing. This is not the point of the article, and because of the multicenter and heterogeneous nature of the data set, we did not feel that the data could be interpreted or applied appropriately in such a manner.

Clinical practice and patient selection varies widely between American surgeons and centers. This article examined surgeon selection at 20 different sites, and these centers generally had an extensive experience with both MIS and open deformity surgeries. Despite such extensive experience, patient selection is a complex and highly individualized process that may be heavily influenced by both patient and physician biases. Because this article sampled a large number of high-volume centers, it is likely reflective of the current state of clinical practice. More robust samples would likely have to involve registries, which would lack a certain granularity of data on radiographic and clinical outcomes measures.

Prior studies have demonstrated the safety and efficacy of a minimally invasive approach when treating ASD.[12-19-25] Anand et al demonstrated a significant improvement in ODI and Visual Analog Scale, while the patients in his retrospective series had an overall complication rate of 21%.[24] Phillips et al also evaluated an MIS technique for correcting adult scoliosis, and they found similar HRQOL outcome improvements and an overall complication rate of 24%.[25] Prior studies on open techniques for the treatment of adult scoliosis have shown overall complication rates between 37% and 87%.[11,26-28] Based on the potential improvements in the complication profile, and potential capacity for improvement in this arena within the elderly specifically, MIS techniques have become increasingly popular for the treatment of ASD. Prior to this study, however, it was unclear whether these techniques have been employed in patients with similar or disparate demographics, radiographic parameters, and disability metrics.

In summary, we have demonstrated that patients undergoing surgical correction of ASD through traditional approaches have slightly larger coronal lumbar deformities, but sagittal baseline characteristics are not substantially worse in this group, when compared with patients undergoing MIS corrective techniques. Notably, patients having MIS surgery for their ASD are older, and this may reflect a greater feasibility in using such techniques in the older, more fragile patient. Despite the differences in baseline characteristics demonstrated in these patient groups, the modest and contradictory differentials seemingly suggest that patients are not specifically selected for one approach or the other based on the specific factors evaluated in this study. It is also important to point out that minimally invasive techniques and technology are in the midst of rapid evolution. The combination of this evolution, along with the consequent learning curve dynamics, results in the potential for patient profiles and selection parameters to change considerably in the future. Patients in the retrospective MIS series were early patients (first few years) in each center's experience and reflect the cautious approach used by individual surgeons based on their level of expertise. Further understanding of the limitations and ceiling effects of these early MIS experiences in spinal deformity correction may help advance the use of MIS techniques for spinal deformity of greater magnitude.[29]

The findings of this study provide support to the recently published MISDEF algorithm that helps guide surgeons in their selection of patients who may be amenable to MIS deformity surgery. Using that algorithm, patients suited for MIS deformity surgery should have SVA under 6 cm, a pelvic tilt under 25°, and PI-LL mismatch of under 30°, which appears to be consistent with the findings in our retrospective review. Future prospective studies should be done to better identify predictive preoperative characteristics, along with postoperative clinical and radiographic outcomes.

Conclusion

Patients chosen for MIS ASD surgery seem to follow a specific patient profile. They are slightly older and have smaller coronal deformities than those chosen for open techniques, but they did not have a substantially lesser degree of sagittal malalignment, although there was trend toward a difference. MIS surgery was most frequently utilized for patients with an SVA under 6 cm, a baseline PI-LL mismatch of under 30°, and a pelvic tilt of under 25°. The results of this study are consistent with the recently created MISDEF algorithm, which may help guide surgeons' choice of surgical approach.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

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